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ON THE GALACTIC SYSTEM

WITH REGARD TO ITS

STRUCTURE, ORIGIN, AND RELATIONS IN SPACE

BY

KARL BOHLIN

WITH 4 FIGURES IN THE TEXT AND 6 PLATES,
INCLUDING PHOTOGRAPHS OF THE PLANETARY NEBULÆ AND OTHER OBJECTS

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On the Galactic System with regard to its structure, origin, and relations in space.

In consequence of a review of nebulæ and clusters in the reach of the refractor of the observatory at Stockholm, and on account of measures in the Globular Cluster Messier 92 [G. C. 4294] recently made,[1] I was induced to take up for further examination a research, previously attempted, on the distribution on the heavens of the different classes of celestial objects, and at first the class of the *Globular Clusters.*

It is, in fact, very striking to any one who has taken up the survey of the sky in conformity with the *Herschelian* classifications, that these marvellous and attracting systems may occupy some peculiar place among the stars and even in the general structure of the Galactic System.

1. *Place of Globular Clusters in the Sidereal System.*

It is surprising that the law of superficial distribution of the Globular Clusters seems to have remained almost unknown in modern astronomical literature, although it forms an immediate feature of the wellknown catalogues of nebulæ and stars. In a recent work, one finds for instance the assertion that »the planetary nebulæ are principally condensated to the Milky Way, while the Globular Clusters are uniformly scattered over the whole celestial sphere», which may be a misapprehension in both statements.

With regard to the statistic researches of stars and nebulæ, it is sometimes pointed out that the observations on the southern hemisphere, made by J. HERSCHEL, may not have been so reliable as to counterpoise the informations drawn from the northern one. The proof of such an opinion is, however, wanting, and on account of the fairly regular distribution of nebulæ and stars on both hemispheres, the doubts in the respect mentioned may be regarded as overthrown, at least as far as only brighter objects are considered. Most of the Globular Clusters belonging to the

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[1] Der zweite Sternhaufen im Hercules, Messier 92; Astron. iaktt. och undersökn. å Stockholms Observatorium Band 8 N:o 3.

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more conspicuous of the celestial objects, the material of which we dispose at present, in respect to these objects, may be regarded as chiefly homogeneous throughout the whole extent of the celestial sphere. After having constructed upon this assumption the charts of Globular Clusters, here reproduced [Plate 1], showing their concentration around a certain point of the Milky Way, I proceeded to search for further information on the subject. The only record on the distribution of the Globular Clusters I thus was able to find, is due to J. Herschel and exhibited[1] by him by the observation of »the extraordinary display of fine, resolved, and resolvable Globular Clusters in the Southern nebulous System, which occurs between $16^h 45^m$ and 19^h in *RA* in the region occupied by *Corona Australis,* the body and head of *Sagittarius,* the tail of *Scorpio* with part of *Telescopium* and *Ara.*» »This», he adds, »is certainly something beyond a mere accidental coincidence.»

In order to obtain a distinct representation of the objects without drawing meridian- and parallel-circles on the charts, a special chart-constructing-circle was employed, consisting of a bar with a polar distance scale and a printing piece, moveable along it, the right ascensions being immediately read and settled on at the borders of the chart. The projection of the scale is the isographic one, giving for annular intervals of the chart the same areas as for zones of the sphere, corresponding to the same limits of polar distance. In this way equal areas of the projection represent equal ones on the sphere.

The positions and the descriptions of the several objects, constructed in the charts, are taken from the *New General Catalogue of Nebulæ and Clusters of Stars for 1860.0 by J. L. E. Dreyer.*[2]

Thus having constructed the two charts representing the Clusters of the southern and northern hemispheres and containing even the general trace of the *Milky Way,* as represented by a line in these charts, the general feature of distribution of the objects around a point [$\alpha = 17^h 40^m$; $p = 125°$], situated in the *Milky Way,* in the constellation of *Telescopium,* at once revealed itself.

The four magnitudes of dots, employed in these charts, refer to Herschel's designations vL, L, pL, S [very large, large, pretty large, small]. At a more assiduous inspection of the spherical conglomerate, made up of these Globular Clusters, and looking away from the two *Maghellanic Clouds,* which seem to contain a considerable number of them, I was struck by some of the objects, generally very faint and appearing to lie outside the limits of the general assemblage of the bodies. The first object, met with in this way, was the cluster N. G. C. 628 [G. C. 372, Messier 74, $\alpha_{1860.0} = 1^h 29^m 11^s$; $p_{1860.0} = 74° 56'.0$], described as Globular Cluster, F, vL, R, vg, psmbM, rr. This object has been photographed by Sir Isaac Roberts[3] and proves to be a very regular spiral nebula with numerous knots included, of which a reproduction is given here.

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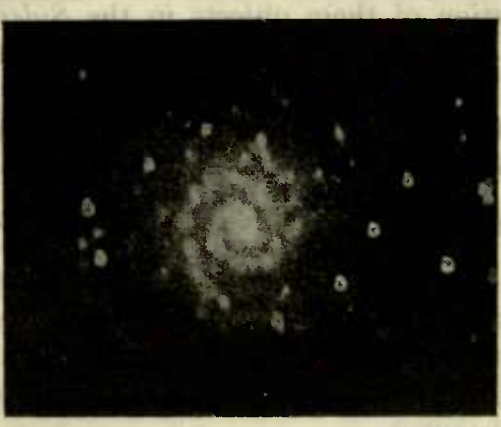
[1] Results of Astronomical Observations, made during the years 1834, 5, 6, 7, 8 at the Cape of good Hope [pag. 136].

[2] Memoirs of the Royal Astronomical Society, Vol. XLIX Part I.

[3] I. Roberts, Photographs of stars, star-clusters, and nebulæ, Vol. II Plate XI.

Fig. 1. Nebula N. G. C. 628; G. C. 372; Messier 74.



There are, moreover, some other objects which, according to their place in the region, occupied by N. G. C. 628, are dubious as to their Globular-Cluster-nature, viz., —

G. C. 68 described as Globular Cluster, vF, cC
G. C. 5224 » » » » , S, R.

These objets, which probably are spiral nebulæ of the same general character as G. C. 372, are excluded from the representation of the Globular Clusters in Plate 1 and marked separately on the second figure of the Plate, which contains all objects excluded.

These few discordances of the descriptions of the N. G. C. from more recent observations are sufficient to point out that a probably considerable number of objects, designed in the catalogue as Globular Clusters, may refer to spiral nebulæ of the known form exhibited by N. G. C. 628. The difficulty in all cases clearly to distinguish the Globular Clusters from other objects expresses itself even by the Herschelian distinctions:

r mottled, *not* resolved;
rr partially resolved, some stars seen;
rrr well resolved; clearly consisting of stars.

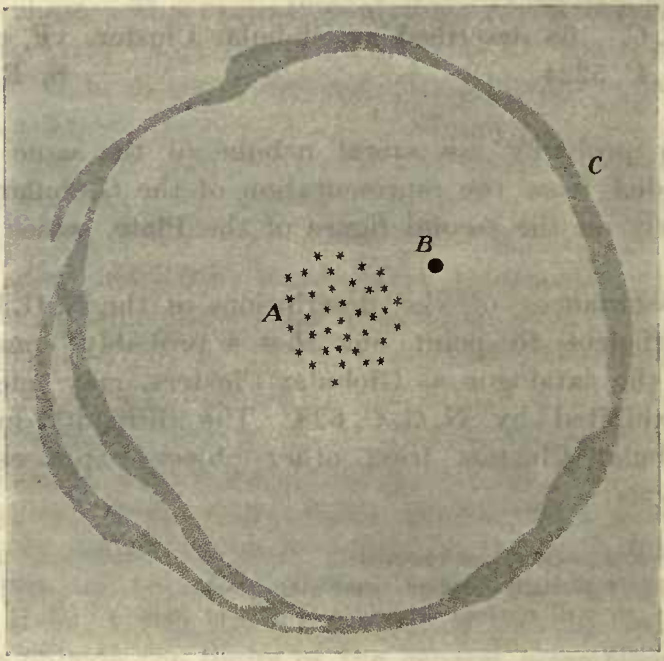
Consequently, the two first classes of objects were omitted in the present research, and thus the reproduction in Plate 1 does not contain other objects than those which in the catalogue either are designed as *rrr* or in respect to which the magnitudes of the stars involved are expressely indicated as *st 11*, *st 14—16* and so on. The objects, thus regarded as doubtful, are represented in the additional charts. It is to be seen that most of the Globular Clusters, contained according to the catalogue in the two *Maghellanic Clouds*, belong to this category. In fact, according to HERSCHEL's classification, there are in the *Nubecula minor* 3 Globular Clusters, two of which are uncertain, and in the *Nubecula major* 5 Globular Clusters, 3 of which are uncertain.[1] After such a classification of the catalogue-material of Globular Clusters, the representation of these objects in Plate 1 may prove to be sufficiently reliable for discussion of the situation of these objects in the *Sidereal System.*

The question how to explain that the Globular Clusters are thus thrown together to one side of the Galactic Circle, the centre of the whole conglomerate coinciding nearly with a point of that circle, can hardly, as it seems, be answered in any other way than by assuming that

The Globular Clusters' System is really situated in the Centre of the Galactic System.

In fact, if this is supposed, one needs only to place the sun with the planetary system somewhat beyond the boundary of the Globular Clusters System in a direction opposite to the apparent place of the centre of the Clusters on the celestial sphere in order to obtain the aspect actually exhibited by the distribution of the Globular Clusters on the heavens.

Fig. 2. *General arrangement of the Galactic System.*



A. Globular Clusters' System;
B. Sun with the planetary system;
C. Milky Way, including the general system of fixed stars, of wich B is the only one represented in the figure.

Thus taking for origo the centre of the Globular Clusters' System the coordinates of the Sun will be

$$\alpha = 5^{h}40^{m};\ \delta = +35^\circ.0,$$

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[1] J. Herschel, Results of Astronomical Observations at the Cape of Good Hope pag. 153 etc, containing the catalogue of objects in the Maghellanic Clouds; Plate X, containing a First Approximation to a Chart of the *Nubecula Major.*

corresponding to a point situated in *Auriga*. The Galactic longitude and latitude of the same point, reckoned from the point of the Galactic circle where the equator of the earth in its motion has its north-ascending node on the Galactic plane, are again:

$$L = 321^\circ 34'$$
$$B = +2\ 56.$$

2. *State of matter in the original body of the Galactic System.*

There is a circumstance able to support the idea of this situation of the Globular Clusters, in the middle of the Galaxy, viz., the *original state* of the body, from which the whole Galactic System may derive its origin. In whatever manner this body otherwise may have been formed, it is very certain that the centre of the body has been overheated compared with the outer parts of it. Consequently, at the time when the matter condensed into the stars,[1] the process at the centre, which took place at a hotter and, on an average, considerably thinner state of the gas than elsewhere in the body, has given rise to dusty condensations dropped into spherical conglomerates, forming what we regard as the Globular Clusters. Farther away from the centre, the gaseous state has had a greater density, and consequently the condensations have here grown larger, forming solid stars of every size. Finally, at the actual boundaries of the system, which may be conceived to have had the shape of a spherical shell or a bubble including matter of exceedingly thin consistency, a physical constitution has prevailed, which by condensation has given rise to the minute white stars now constituting the *Milky Way*. It is of course incorrect to ascribe the variations of state of matter in such a body only to unequal temperature in the common sense of the word. The matter of the original body may rather be conceived to have been in an explosive state, far exceeding in thinness the gaseous state of matter to which we are accustomed. And although this cannot be directly proved, it seems notwithstanding very probable, by considering the luminous state of many of the very bright planetary nebulæ, which appear to be at distances exceeding those of the faintest stars.[2]

At this state of matter, discontinuities of consistency, corresponding in some degree to the passage from fluid to gaseous state, may have occurred, which by condensation have given rise to the various condensed products referred to above.

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[1] To confer the investigations of GWILYM OWEN and A. LL. HUGHES on *nucleating temperature*. Philosophical Magazine 1908, ser. 6, Vol. 15 p. 746—761.

[2] Indications of negative parallaxes are at present known for the planetary nebulæ G. C. 1532. [Astr. Nachr. N:o 4240]; G. C. 4964 and N. G. C. 7027 [Astr. Nachr. N:o 4254]. The parallax of the Ring-nebula in Lyra is, accordingly to Newkirk's recent calculations, evanescent.

3. *On spectra of gaseous nebulæ.*

It is obvious that the gaseous nebulæ exhibit examples of such a very exaggerated state of matter, here supposed once to have characterised the body, of which the Galaxy is the present product. At first, the extraordinary brightness of many of them, namely of the »blue nebulæ», shows that the intrinsic luminosity of these bodies far exceeds that of condensed stars at even the highest temperatures. But, furthermore, the known constitution of their spectra plainly exhibits the same thing. In fact, the continuous spectrum, frequently accompanying the gaseous lines in the nebular spectra, seems to be at any rate foreign to the true nebulous state. In the planetary nebulæ G. C. 4234, 4373, 4390, 4628, **Vogel**[1] observed the continuous spectrum, more or less weakly developed from about $0^{\mu}.600$ to $0^{\mu}.470$, while, according to the same author, the continuous spectrum is wanting in the planetary nebulæ G. C. 4510, 4532, 4572.

The nebulous lines themselves, of which, according to **Campbell**, there exist a considerable number,[2] two of which, however, are to be regarded as characteristic, are principally four, viz.

$\lambda_1 = \overset{\mu}{0}.5007$ *first chief nebular line*
$\lambda_2 = 0.4959$ *second* » »
$\lambda_3 = 0.4862$
$\lambda_4 = 0.4341.$

The line $\lambda_3 = 0^{\mu}.4862$ is generally and the line $\lambda_4 = 0^{\mu}.4341$ frequently present in the spectra of gaseous nebulæ. These lines correspond, according to **Huggins**[3] and **Gothard**[4], resp. to the hydrogen lines H_β and H_γ. The first chief line was originally ascribed by **Huggins**[3] to nitrogene. But as the latter is seen to be double, the nebular line being single, the coincidence must be accidental. The second chief line, nearly coinciding on the one side with a barium-line and on the other with an oxygen-line, cannot be indentified with any known substance.[5] It is, moreover, to be noticed that the first of the hydrogen-lines, $\lambda = 0^{\mu}.656 = H_\alpha$ is absolutely absent from the nebulous spectrum. This is also the case with many of the variable stars, as R Andromedæ, V Cassiop., and B Lyræ. According to **Keeler**[5], the lines of the nebulous spectrum are due to a very high temperature of the nebulous matter. He adds that the first chief nebulous line seems to be absolutely monochromatic, which, in fact, will support the idea of an extremely exaggerated state of matter in the nebulous bodies.

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[1] Astron. Nachr. N:o 1864 and N:o 2854.

[2] W. W. **Campbell**, Spectra of the great nebula in Orion and other wellknown nebulæ. Astronomy and Astrophysics Vol. XIII, 1894 pag. 494.

[3] Philosophical Transactions 1868.

[4] Astronomy and Astrophysics, Vol. XII, 1893, pag. 55.

[5] J. E. **Keeler**, Spectroscopic observations of Nebulæ, Publications of the Lick Observatory, Vol. III, 1894.

It is at last interesting, in respect to our ideas here proposed, to recall in mind an opinion, expressed by W. HUGGINS,[1] viz., — that the gaseous nebulæ may possibly belong to an order of cosmical bodies, distinct from that represented by the sun and the fixed stars. As I was acquainted with this memoir of HUGGINS after having formed my opionion, referred to above, on the resemblance and the probable identity in general structure of the *Galaxy* and the planetary nebulæ, the hypothesis gains in probability.

4. *Nuclei of Ring Nebulæ.*

The nuclei of most of the Ring Nebulæ as for example the Ring Nebula in *Lyra*, G. C. 4447, have a peculiar spectrum of yellow and green light, in such a degree as to make it necessary considerably to adjust the eyepiece to see the nucleus. According to KEELER[2], there can hardly be any doubt that the central star is actually formed from the nebula by a process of condensation; but it is not merely a brigther portion of the nebula, emitting radiations of the same character as the rest, the nucleus being so nearly approaching to the stellar character that the general distribution of light in its spectrum is that of an ordinary star. According to photographs taken by J. SCHEINER[3] and E. GOTHARD[4], similar centres are shown in the nebulæ G. C. 4628 and G. C. 4964.[4] These facts are in accordance with our conceptions of the original state of the Galactic System and of its having in the centre a particular body of globular clusters, condensed in the singular manner above referred to.

The nuclei of the Ring Nebulæ are, moreover, frequently very slight and faint, compared with the whole of the nebulous body, as even is the case with the Globular Clusters' System compared with the Galactic System on the whole.

5. *Various forms of Planetary Nebulæ.*

The most conspicuous of the planetary nebulæ is the Ring Nebula G. C. 4447 in *Lyra*. The adjoined reproduction of this nebula, Plate 5 N:o 5, shows the nebula in the form, ascribed to it by the late Miss CLERKE and others, as exhibiting rather an open than a closed ring, similar to the typographic sign of a big parenthesis, with a slight nucleus in the middle. An even more striking example of ring nebula is offered by the pale planetary nebula G. C. 2343, which is of considerable size. The adjoined photograph of this nebula, Plate 5 N:o 1, shows the nebula to be nearly of the same form as G. C. 4447. But the actual form of the nebulous body is here even more obvious than in the former case. One may construct a model of these nebulæ, by forming of a slip of paper a cylindrical ring, which, when seen obliquely, almost exactly offers their general appearence.

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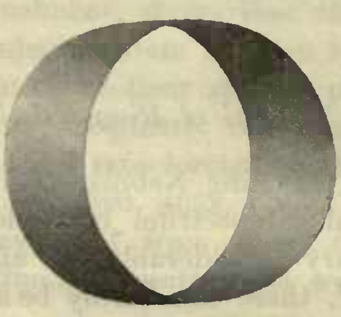
[1] S. HUGGINS. On the spectra of some of the nebulæ. Proceedings of the Royal Society, Vol. 156: 1, 1866. pag. 392.

[2] KEELER, On the central star of the Ring Nebula in Lyra. Astr. Nachr. N:o 3111.

[3] J. SCHEINER, Über die planetarischen Nebel h 2098 [G. C. 4628] und h 2241 [G. C. 4964] Astr. Nachr. N:o 3086.

[4] E. GOTHARD, Photographische Aufnahmen Astr. Nachr. Vol. 115 pag. 221.

Fig. 3. *Model of Ring Nebula.*



It can hardly be doubted that this also is nearly the actual form of the ring nebulæ G. C. 4447 and G. C. 2343 and of other Planetary Nebulæ, which thus chiefly consist of a hollow and almost cylindrical shell, the cavity of which contains nebulous matter of thinner consistency, being moreover condensed at the centre to the nucleus there visible.[1] The fig. 3 shows the projection of a model of Ring Nebula.

There is, as far as is known, but a single instance of a nebula, fit to explain this singular and typical form of ring nebulæ, viz., the Dumbbell-Nebula G. C. 4532, a reproduction of which in Plate 4 N:o 1 shows the features of this body very plainly. If it is supposed that this nebula is carried to its actual form from a hollow spherical shell, which is broken down at its poles, it becomes at once obvious that the nebula, if seen in the direction of its polar axis, would exhibit the general form of a ring nebula. As the process once is carried further, the remaining shell will gradually be reduced to an equatorial zone, more approaching to the cylindrical form described above.

While the nuclei of the ring nebulæ are very small, and the inner parts of these nebulæ are very diluted, as to make the impression of vacuity, the *closed planetary nebulæ* have generally a circular and comparatively big centre, of great luminosity, surrounded by a stratum of atmospheric appearance, which in various instances is more or less extended. Such nebulæ are G. C. 4514, G. C. 4234. In some cases, the atmosphere is too insignificant to be marked at all, such nebulæ forming a transition to *nebulous stars*,[2] some of which, on the other hand, present atmospheric appendices in the form of lateral jets of nebulosity as for example the nebula G. C. 1532, Plate 4 N:o 7. In order to explain these closed forms of planetary nebulæ as products of exaggerated matter, originally contained in a superficial hide or shell, as above mentionned, it is to be supposed that the evolution of such nebulæ is far more advanced than in the case of the proper ring nebulæ. Thus, in some cases, the ring itself proves to be condensed to a more cloudy form of a striking resemblance to a *Via Lactea.*[1] But in most cases, even such a remainder of the primitive shell has vanished, either by gathering to an atmosphere around the general centre of the nebula as in G. C. 4234 and G. C. 4514 or in giving off so much of its light as to be quite invisible. In fact, the prolonged exposure of some objects of this kind, extended for example to 4 hours for G. C. 1532, does not bring out any trace of atmosphere or *Via Lactea.*

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[1] J. Herschel in his Outlines Ed. 1851, pag. 604, says about the Nebula G. C. 2343 [$\alpha = 11^{h}\,4^{m}$; $p = 34^{\circ}\,4'$]: »The light of this stupendous globe is perfectly equable (except just at the edge, where it is slightly softened) and of considerable brightness. Such an appearence would not be presented by a globular space uniformely filled with stars or luminous matter, which structure would necessary give rise to an apparent increase of brightness towards the centre in proportion to the thickness traversed by visual ray. We might, therefore, be induced to conclude its real constitution to be either that of a hollow spherical shell or of a flat disc.»

[2] A possible connection of planetary nebulæ with nebulous stars is pointed out by W. Herschel in the Philosophical Transactions, Vol. 20, 1802 pag. 501, 502.

It is to be noted, that these closed nebulæ are generally very bright, with a colour of blue, verging upon green.

A most interesting form of planetary nebula is exhibited by the above mentioned G. C. 3258, Plate 5 N:o 3. This nebula has a big central nucleus, the atmosphere of which proves to be separated from the nucleus, forming around the centre a cloudy peripheric ring, irregularly deformed and broken as to have the appearence of a Milky Way, surrounding the central body of the nebula.

6. *The distribution of stars in the Galactic System.*

In the Vol. 31, 1817 of the Philosophical Transactions, in the *Concluding remarks* (*p. 330*) *to Astronomical observations and experiments tending to investigate the local arrangement of the celestial bodies in space and to determine the extent and condition of the Milky Way*, W. HERSCHEL expresses as his opinion that »What has been said of the extent and condition of the milky way in the several papers on the construction of the heavens, with the addition of the observations, contained in his attempt to give a more correct idea of its profundity in space, will nearly contain all the general knowledge we can ever have of this magnificent collection of stars». The results, referred to with these words, and the proceeding of research are well known. The instrument employed was the 20-feet reflector of 19 inches aperture. H. selected a pretty broad stripe crossing the milky way at right angles and counted the numbers of stars in 3400 fields of view belonging to the stripe at six different zones, the total number of stars of the heavens, thus estimated, amounting to 20 millions, of which 18 millions in the Milky Way itself. In the same manner, J. HERSCHEL counted 2299 fields of view of the southern hemisphere. It was concluded from these gauges that the stars, if supposed uniformely distributed, are arranged together in a body, the boundaries of which form a lens, whose greatest and smallest dimensions have the ratio of 5.5 to 1. In the further progress of his researches (Memoir

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[1] G. C. 3258, Plate 5 N:o 3, is an example of this kind.

1802) HERSCHEL delivers himself from this somewhat starry idea, and expresses the opinion that the Milky Way is made up of stars, which are otherwise scattered than the stars in our vicinity. And in the memoir of 1811, it is expressely pointed out that the assumption of uniform distribution of the stars is to be given up for the Milky Way and for the star groups.

After HERSCHEL, the most complete inquiry of the distribution of stars is due to SEELIGER, by his recent researches, based on the »Durchmusterung» of stars by ARGELANDER and SCHÖNFELD (magnitudes 1—9), the CELORIA stars, comprising inclusive the 11.5 magnitude, and finally the Herschelian gauges as completed by HOLDEN u. The researches of SEELIGER can be summed up as follows. The ARGELANDER SCHÖNFELD stars are divided into seven classes, namely:

Class	Magnitudes
1	1.0 to 6.5
2	6.6 » 7.0
3	7.1 » 7.5
4	7.6 » 8.0
5	8.1 » 8.5
6	8.6 » 9.0
7	9.1 » 9.5

For every class, the number of stars in every quadrangle of a reticule, disposed after equal differences of right ascension and declination, is summed up. Hence it is easy to evaluate the density of stars per square degree in the different quadrangles of the sphere. These numbers, arranged in a table with double entrance, constitute the material, suitable for the inquiry. S. divides, furthermore, the celestial sphere into zones, parallel to the Milky Way, each 20° in breadth. Thus one gets nine zones, of which the ninth, comprising the south pole, is still left out of account. The fifth zone comprises the Milky Way. There is no difficulty to confine, within lines drawn in the tables, the numbers corresponding to every Galactic zone. The concentration of stars of all seven classes to the plane of the Milky Way is thus plainly shown. If the density of the fifth zone is taken for unity, the average density for the star classes 1—7 is got up as follows:

Zone	Stars density
1	0.35
2	0.36
3	0.45
4	0.68
5	1.00
6	0.77
7	0.47
8	0.41
9	—

Hence

$$\delta = \frac{\text{polar density}}{\text{equatorial density}} = \frac{1}{3}$$

and consequently[1]

$$\alpha = \frac{\text{polar axis}}{\text{equatorial axis}} = \sqrt[3]{\delta} = \frac{2}{3}$$

In order to investigate any inequality of distribution for the different magnitude classes, the *gradient* (variation of density) for every class is computed. This number exhibits a somewhat greater condensation for the fainter stars than for the brigther ones. According to the charts constructed by Stratonoff,[2] on similar principles, this condensation becomes more conspicuous only from the magnitudes 7.6—8.0.

In a following memoir [Abh. d. K. Bayerischen Akademie d. Wissenschaften 1899], the researches of Seeliger are continued with more particulars. The general assumption, according to which the stars are, on an average, equally luminous and equidistant, is shown to agree very nearly with the actual distribution of stars, the stars up to the

nth magnitude

being approximately *four* times as numerous as the stars up to the

n—1th magnitude.

A sligth discordance from this general law is, however, so far marked, as *the number of stars from the sixth to the ninth magnitude increases somewhat more slowly than according to the general law just quoted.* Hence the actual density of stars diminishes towards the boundaries of the stars' system. Furthermore *the increase in number of stars with increasing index of magnitude proves to be greater, the nearer the considered region of the heavens comes to the Milky Way.*

The examination of stars up to the $11\frac{1}{2}$ magnitude, carried out for the interval between 0° and 6° Declination by *Celoria* at the Milano Observatory, exhibits the fact that those stars behave in respect to the Milky Way in the same manner as the stars of the first magnitudes [$1^{\mathrm{m}}.0$ to $9^{\mathrm{m}}.0$]. These Celoria-stars are of the greatest interest in constituting a passage from the Argelander-stars to the Herschelian stars. S. takes up in his researches also the last mentioned stars, comprising 683 fields of view, supplied with 405 fields not made known by H. and lately published by E. Holden. According to the photometric scale these stars extend to the 13th and 14th magnitude. The behaviour of these stars seems to be a very different. While the Celoria-stars are disposed approximately in proportion to the Argelander-stars, the proportion of density, for the Herschelian stars, varies from 33 at the pole of the Galaxy to 274 in the Milky Way. *The number of the faintest stars increases also in*

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[1] According to Herschel is $\alpha = \frac{2}{11}$.

[2] W. Stratonoff. Publications de l'observatoire astronomique et physique de Tachkent N:o 2, 3.

the regions far from the Milky Way very slowly and considerably less than for the brigther stars. But in the Milky Way the increase in number for the Herschelian stars seems, according to S., to be less — and is surely not greater — than would be the case, if the Herschelian stars were distributed according to the law holding for the stars up to the $11\frac{1}{2}$ magnitude. From the whole inquiry, S. concludes that the Milky Way cannot be an independent phenomenon, but must cohere with the constitution of the stars system on the whole.

It may, however, be pointed out that the Milky Way, considered as a portion of the general system of the stars, may nevertheless be of a comparatively singular structure and almost separated from the system of the brighter stars. Further examination fully proves that the Argelander-stars fail to show anything corresponding to the varieties of density exhibited in the peculiar structure of the Milky Way.

Taking into account these several researches, the general result may conveniently be thus expressed.[1]

»If we should remove from the sky all the local aggregations of stars and also the entire collection which forms the clouds of the Milky Way, we should have left a scattered collection constantly increasing in density toward the Galactic belt. It does not yet seem possible to decide whether the agglomerations of the Milky Way lie on the boundary of the universe or not.»

By treating more recent material, mainly containing star gauges by Pickering, Parkhurst, Hagen, and de Sitter, added to the Herschelian gauges and the Carte du Ciel plates hitherto published, Kapteyn has proceeded to investigate the distribution of stars even up to the 16th magnitude. The result arrived at is that of a symmetrical distribution of stars in respect to the Galactic circle, confined in the formula[2]

$$\log N = g\left[\frac{1}{\sqrt{\pi}}\int_{-\infty}^{k} e^{-x^2}\,dx - c\right],$$

in which

N = number of stars of magnitude m and brighter per square degree, in Galactic latitude C; g, k, c being constants, which are pure functions of the Galactic latitude, for instance:

$$k = 0.0460 - 0.0162 \operatorname{Cos} 2\,C.$$

As this value of k is very small, the formula shows that very nearly:

$$\frac{N}{N_0} = h^m$$

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[1] S. Newcomb, The stars, London 1902, pag. 276, 320.

[2] The Observatory, Vol. XXXI, N:o 393, pag. 74.

where m is the highest magnitude considered, N_0 and h being functions of the latitude — approximately:

$$h = 4.$$

Other papers on the distribution of stars are:

A. M. Clerke. The distribution of stars, Astronomy and Astrophysics 12: 1893 pag. 515;

T. W. Backhouse, The Sidereal Universe, referred to in the Monthly Notices of the Royal Astronomical Society Vol. L pag. 374;

R. A. Proctor, Statement of views respecting the Sidereal Universe, Monthly Notices Vol. XXXIII, pag. 539;

J. Herschel, On the law of distribution of nebulæ and clusters of stars over the surface of the heavens. Results of astronomical observations, made at the Cape of Good Hope, pag. 133.

7. *Distribution of Spiral Nebulæ.*

The attention to a certain law of distribution of the nebulæ was raised by J. Herschel with a statistic inquiry, by which he succeeded in pointing out two vast dominions of nebulæ, each surrounding the poles of the Galaxy. This numerical statement, which, according to Herschel, must be considered as the expression of a real law of nature, was furthermore left unexplained.

The next one to take up the question of the distribution of nebulæ was Cleveland Abbe.[1] His researches refer to the distribution of different classes of celestial objects, viz, — 1) Clusters, 2) Globular Clusters, principally condensed in the Milky Way, 3) »resolvable nebulæ», of which merely 12 of 397 are in the Milky Way, 4) unresolvable nebulæ of which only 64 of 4053 are situated in the Milky Way. The conclusions are confined in the following suggestions:

1. The Clusters are members of the *Via Lactea* and are nearer to us than the average of its faint stars.
2. The Nebulæ resolved and unresolved lie, in general, outside the *Via Lactea*, which therefore is essentially stellar.
3. The Visible Universe is composed of systems, of which the *Via Lactea*, the two *Nubeculæ* and the *Nebulæ* are the individuals.

The author conceives the paucity of nebulæ in the immediate neighbourhood of the *Via Lactea* to be partially due to the comparative glare of the intervening multitude of stars; but their persistent paucity, when the limits of that band are supposed greatly increased (to $^8/_{36}$ of the entire celestial surface) implies, according to him, that the Nebulæ are actually either fainter or scarcer in the neighbourhood of that plane, or that the visible universe is less extended in that direction. Cleveland Abbe gives also a statistic of planetary nebulæ, which he finds follow almost the law of distribution for the Clusters. In accordance with his previous views, the planetary nebulæ may be classed with the clusters as regards their arrangement and distance from us, and are to be considered as gaseous globes belonging to the Via Lactea. Yet this later conviction may be subjected to some doubt, as a more particular discussion of the distribution of the *Planetary Nebulæ* comes up to prove.

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[1] On the distribution of the nebulæ in space. Monthly Notices of the Royal Astronomical Society, Vol. XXVII, 1867 pag. 257.

A more complete account of the distribution of the Nebulæ is given by PROCTOR[1] in the form of isographic projection charts, showing the concentration of these bodies into two great systems more clearly than a merely numerical table is able to do. The four pairs of maps are laid down from the table prepared by CLEVELAND ABBE. The author points out a somewhat stratified aspect of the northern group of nebulæ, which permits to understand the conception of W. HERSCHEL that the nebulæ might be arranged in a zone, somewhat resembling the Milky Way, but nearly at right angles to it. On closer inspection, he recognizes a certain streamy character of the groups in both hemispheres. The pair of maps, numbered III, is especially fit to bring out the great vacant zone, along the Milky Way, for the nebulæ, which, according to the author, is to be considered as the most significant of all the features, presented by the nebular system. This and the further considerations of the author are closely related to the researches of CLEVELAND ABBE in his memoir just quoted. The assertion of Proctor with regard to his pair of charts, numbered IV, containing the stellar system together with the nebular scheme, that the lucid stars show a tendency of clustering at the same points, where condensations of nebulæ are prevailing, rests open to question. According to PROCTOR, the vacancies of nebulæ in places of the heavens outside the Galaxy are marked by absence of bright stars.

These valuable researches of PROCTOR induced a new investigation of the matter by SIDNEY WATERS.[2] The charts constructed by this author contain all the objects recorded in J. HERSCHEL'S general catalogue of 1864. They are very beautifully laid down and show plainly the mutual distribution of clusters and nebulæ.

As a complement to the charts of the Globular Clusters, the present memoir contains also three pairs of maps, showing the distribution of the spiral nebulæ[3] in two vast dominions arround the poles of the Milky Way. The maps are confined to the nebulæ designed in the *New General Catalogue* as bright B or very bright, vB. The three pairs of charts contain, respectively, the nebulæ designed as 1) round R, 2) extended or little extended E or lE, 3) very extended or exceedingly extended vE or eE. In every case the concentrations referred to are clearly visible, the dominions of the round nebulæ being the most vast and the very extended nebulæ being most constricted towards the poles of the Milky Way.

The mutual relation of the Milky Way and the dominions of the spiral nebulæ seemed to me, for long a time, to be the most wonderful enigma of the heavens, until the probable explanation of this behaviour revealed itself at a closer examination of the structure of the Milky Way. It is in fact impossible, by regarding the peculiar structure of the body of the Milky Way, to join in the spiral theory, attempted by some astronomers, and not to acknowledge its substantially circular form. The principal rifts or ramifications of the Milky Way seem, at a closer examination, not to be understood otherwise than as real rifts in an originally integral body of gaseous matter, thoroughly as rifts arise, owing to stresses, in the common atmospheric clouds. The strain which once produced the great ramification of the Milky Way must, on these hypothesis, have been directed vertically to both sides of the great circle of the Milky Way, and it becomes thus at once very probable that its cause is to be searched for in the breaking down at its poles of a great spheroidical shell of matter, which originally formed the body of the Galaxy. In fact, of the mechanical consequences of such a transformation are to be noted: possible rifts in the remaining equatorial regions on account of loss of continuity along certain lines of least density; furthermore obstructed parts of the polar regions, which may have resulted in the groups of spiral nebulæ[1], at present observed arround the poles of the Galaxy. It is very clear, indeed, that the matter in such a shell should possess a higher degree of conservative coherence at its equator than at its poles, where no supporting force balances the gravity, as soon as the inner substance of the body begins to condense into clustering parts. Analogies to the supposed diversity of matter at the poles and at the equator of such a shell are furnished by the wellknown features of solar rotation at the Sun's equator and at its poles.

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[1] R. A. Proctor, Distribution of the Nebulæ. Monthly Notices of The Royal Astronomical Society. Vol. XXIX, 1869 pag. 337.

[2] The distribution of Clusters and Nebulæ, Monthly Notices of the Royal Astronomical Society, Vol. XXXIII, 1873, pag. 558.

[3] A typical example of these nebulæ is for convenience reproduced in Plate 6 N:o 7.

The hypothesis, thus formed on the original state of the Galaxy, receives an important support by the actual view according to which some of the planetary nebulæ may be bodies whose substantial state is that of a luminous shell of matter. According to my opinion, the breaking down at the poles of the nebulæ has in most cases taken place, leaving as a fragment a substantially cylindrical equatorial ring, the products, supposed to exist at the poles, being invisible on account of their comparatively faint luminosity. A striking example of this fact is afforded by the *Dumbbell Nebula G. C. 4532,* in which the process of breaking down at the poles seems to be actually going on.

8. *Distribution of planetary nebulæ.*

One finds sometimes the assertion that the planetary nebulæ are situated in the Milky Way or near it. This view is for instance expressed by CLEVELAND ABBE. In his memoir, referred to above, he asserts that the planetary nebulæ may be classed with the Clusters as regards their arrangement and distance from us, and are to be considered as the gaseous globes belonging to our Via Lactea. PROCTOR does not partake of this view, for in his study, referred to above, he only maintains that the irregular gaseous nebulæ are all on or close to the Milky Way, except one etc. Even WATERS expresses himself on the subject in a somewhat undecided manner, in observing that the complete segregation of all the nebulæ (the gaseous nebulæ excepted) from the Galactic zone is equally remarkable as the aggregation of clusters in the neigbourhood of the Galaxy. Sir WILLIAM HUGGINS' view with regard to the planetary nebulæ was referred to above and contains nothing as tho their distribution. In several popular works the assertion of the distribution of the planetary nebulæ along the Milky Way is repeated.

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[1] The recent determination of the parallax of the Andromeda-nebula [Astron. iaktt. och unders. Bd 8 N:o 4] affords an additional proof of the connexion of spiral nebulæ with the stars system.

Such a close distribution along the Milky Way would meanwhile prove to be contradictory to our hypothesis that the *Galaxy* and the *Planetary Nebulæ* are to be regarded as coordinated celestial objects. It became, therefore, important to take up the question of the distribution of the planetary nebulæ again. The charts thus constructed [Plate 3], involving all the planetary nebulæ of the New General Catalogue, afford, indeed, no indication of an exclusive concentration of these bodies to the Milky Way. They show rather a somewhat *uniform distribution* of the planetary nebulæ over the celestial sphere. By excluding the objects designed by H. as questionable, a slight tendency to gathering in respect to the Milky Way seems nevertheless to become prevailing.

In this respect, it is further to be remarked that the nebulæ, denoted *planetary and stellar* in DREYER'S catalogue, are excluded from our statistics. It should furthermore be noted that the classification of the planetary nebulæ in HERSCHEL'S *General Catalogue* may be somewhat uncertain. I have, however, hitherto found no one object that seems to have been erroneously classed by Herschel as a planetary nebula. Thus the distribution of the planetary nebulæ seems rather to be in favour of our hypothesis on the relations of these bodies to our Galaxy than against it.

9. *On stellar nebulæ.*

It is obvious that most of the stellar nebulæ are small planetary nebulæ. It is, however, impossible to associate these objects with the statistics of the planetary nebulæ, because they have not been investigated in a systematic manner. Most of these not very numerous objects have been found by R. COPELAND[1] and by E. C. PICKERING[2] and are tested spectroscopically as gaseous bodies. COPELAND announces a few such objects, found in May and April 1883. In a short note, he adds five objects found by a number of sweeps over the heavens in the richer part of the Milky Way about Cygnus.

PICKERING enumerates, in a short note, 11 stellar nebulæ between $18^h 25^m$ and $19^h 29^m$ of Right Ascension. The objects were discovered during an extensive examination of the stars with the aid of a direct vision prisme. They are mostly undistinguishable from stars, when the prisme is removed from the eyepiece, but a few of them have small discs. He points out that »the regions examined have been selected with the view of affording a fair means of learning something with regard to the distribution of these objects in the sky, and that it is remarkable that all those which have been found occur in or near the Milky Way.» He adds that »this was previously known to be the case with the larger planetary nebulæ, having gaseous spectra» No further account as to the extent of the researches is given.

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[1] R. Copeland, An account of some recent astronomical experiments at high elevations i the Andes. Copernicus Vol. III pag. 206.

R. Copeland, Spectroscopic observations, made at the Earl of Crawfords Observatory, Dun Echt. Aberdeen, Monthly Notices, Vol. XLV pag. 90, 91.

[2] E. C. Pickering, Small planetary nebulæ, discovered at the Haward College observatory. The Observatory 1882, pag. 294, 295.

10. On the Wolf-Rayet stars.

These stars, having peculiar spectra, are of all celestial objects those which show the most decided concentration to the Milky Way. Indeed, of 55 known objects of this category all are situated within 9° to both sides of the Galactic circle. The distribution shows, according to W. W. CAMPBELL[1], two maxima at about 60° and about 246° of Galactic longitude, a fact which, to some degree, reminds of the distribution of sunspots on two opposite sides of the Sun's equator. These features are, however, not decisive for the planetary nebulæ, though a resemblance of the spectra was pointed out by PICKERING. Later CAMPBELL contradicts (l. c.) this similitude of spectra, remarking (pag. 475) that »in conclusion the spectra of the Wolf-Rayet stars are not closely related to any other known type».

11. On large gaseous nebulæ in the Milky Way.

Though the planetary nebulæ are not generally members of the Milky Way, there exist in it or in its neighbourhood, other gaseous nebulæ of great extent. Such nebulæ are: the Orion Nebula; the great nebula G. C. 4616 in Cygnus, Roberts II, plate 21;[2] N. G. C. 281 Cassiop., Roberts II, plate 22; N. G. C. 1499 Persei, Roberts II, plate 22; M 16 Clypei, Roberts II, plate 23; Neb. 37 Cygni, Roberts II plate 24; Neb. 74 Cephei, Roberts II, plate 24; Nebulæ in the Pleiades; G. C. 600 Ceti, Roberts I plate 10, and others. These nebulæ are well to be distinguished from the planetary nebulæ.

12. Concluding facts and hypotheses.

1. The *Planetary Nebulæ* consist originally of rotating luminous shells filled with very thin matter. In the course of their evolution, the shells break down at their poles, forming apparent *Ring Nebulæ*, with mostly distinguishable *Nuclei*. — At a further stage of development, a big, bright, and extended centre sometimes arises,

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[1] The Wolf-Rayet stars, Astronomy and Astrophysics Vol. 13, 1894, pag. 450.

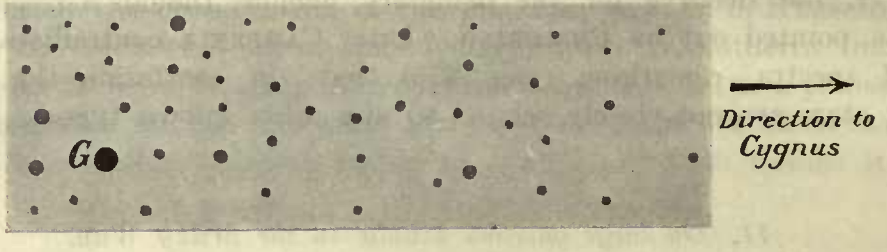
[2] Isaac Roberts, Photographs of nebulæ and clusters of stars, Vol. I, II, London 1893, 1899.

surrounded by fainter nebulosity of atmospheric appearance. This is the case of the *Closed nebulæ.* Some of these objects are referred to as »blue nebulæ» other as »pale nebulæ».

2. The *Galactic System* is supposed to have been such a planetary nebula, which in the manner above described has broken down at its poles, being at present at a pretty advanced stage of a Ring Nebula. The centre of the System is pointed out by a *Nucleus* consisting of the assemblage of the *Globular Clusters.* The *Spiral Nebulæ* around its poles are to be considered as the products of the broken parts of the shell, while the *Milky Way* again is derived from its equatorial belt. Therein exist at present certain *irregular gaseous nebulæ* of great extent, due to latter collisions and frictions, by which the original state of matter, once characteristic of the ring nebula, have been revived.

3. The *Planetary Nebulæ* are considered as the individuals of a stratum — as it were a shoal of worlds — of even considerable breadth and thickness.

Fig. 4. *Stratum of Planetary Nebulæ.*



By placing the Galaxy at G near the head of the stratum and somewhat to the side, one accounts easily for the particulars of spherical distribution of these objects; especially for the abundance of bright planetary nebulæ and stellar nebulæ in the regions about *Cygnus,* and for a still existing sligth tendency to concentration of these nebulæ in respect to the Milky Way.

List of Objects. Plate 4.

Object	Right Ascension, 1900.0	Annual Precess.	Declination 1900.0	Annual Precess.	Description.
G. C. 4532	19^h 55^m 17^s	+ 2^s.59	+ 22° 26′.8	+ 9″.6	»Dumbbell Nebula», Messier 27, *according to Herschel* »very bright, very large, binuclear, irregularly extended.» The appearence of the nebula is the generally known, with the polar nebulosities well marked.
N.G.C.7026	21 2 55	+ 2.06	+ 47 26.7	+ 14.3	Discovered by Burnham 1873 (Monthly Notices 52 p. 45), »pretty bright, binuclear, planetary.» The original plate shows the nebula to be binuclar and probably of the Dumbbell Nebula type with large polar nebulosities). No other nebula of this type is known.
N. G. C. 7026	»	»	»	»	Reproduction of the same object on a smaller scale.
G. C. 298	1 11 21	+ 3.17	+ 12 23.4	+ 18.9	»Faint, large, little extended, very gradually little brighter in the middle.» The appearance of the nebula is almost that of a spiral-nebula.
G. C. 801	3 58 23	+ 5.11	+ 60 39.0	+ 10.3	»Planetary, pretty bright, pretty small, very little extended, 1′ diam.» A very regular ring-nebula.
G. C. 1225	5 36 37	+ 3.28	+ 9 2.0	+ 2.1	»Planetary, pretty bright, very small, very little extended.» Small, little extended nebula, almost uniform with defined border. The original plate shows it to be a dense regular ring nebula with a minute nucleus, seen projected on the side.
G. C. 1532	7 23 15	+ 3.56	+ 21 7.0	— 7.0	»Bright, small, round; star 9 m in the middle.» Very bright central body, with a lateral jet of nebulonsity.
G. C. 1546	7 30 21	+ 3.95	+ 35 26.5	— 7.6	»Pretty bright, considerably small, very gradually very little brighter in the middle, resolvable, almost planetary.» From three plates this object appears to be a partly visible ring-nebula. The visible part is little deformed, and surrounded by fainter and irregular nebulosities. A pretty large nucleus is perceivable.
G. C. 2158	10 32 33	+ 3.77	+ 54 1.3	— 18.6	»Considerably bright, pretty large, round, very gradually, very suddenly much brighter in the middle, nucleus 15″.» Bright centre, from which a curved wisp issues. Faint stripes of nebulosity surround the brighter part of the nebula. The centre proves to be *trifide*.

List of objects. Plate 5.

Object	Right Ascension 1900.0	Annual Precess.	Declination 1900.0	Annual Precess.	Description
G. C. 2343	$11^h\ 9^m\ 0^s$	$+ 3^s.51$	$+ 55° 33'.7$	$- 19''.5$	»Planetary, very bright, very large, round, very gradually, very suddenly brighter in the middle.» Cylindric ring-nebula.
G. C. 2620	11 51 16	+ 3.17	+ 55 40.9	— 20.0	»Bright, pretty large, round, gradually, suddenly brighter in the middle, disc.» The object is obviously a ring nebula. Only a single plate is available.
G. C. 3258	12 46 11	+ 2.84	+ 41 39.9	— 19.7	»Very bright, large, irregularly round, very suddenly very much brighter in the middle, bright nucleus, resolvable.» Bright peripheric nebula surrounds a pretty big nucleus. The object is perhaps the brightest nebula of the northern sky,
G. C. 4234	16 40 18	+ 2.51	+ 23 59.2	— 6.9	»Planetary, very bright, very small, round, disc & border.» Closed nebula. Disc and border clearly seen. Type G. C. 4514.
G. C. 4447	18 49 52	+ 2.23	+ 32 54.3	+ 4.3	»Ring nebula, bright, pretty large, considerably extended (in Lyra).» Cylindric form, Nucleus and atmospheric appendices well marked.
G. C. 4487	19 13 35	+ 2.93	+ 6 21.3	+ 6.3	»Planetary, faint, large, round, very suddenly brighter in the middle.» Ring nebula of type G. C. 2343. There are perhaps, to the northern side, remainders of polar matter.
G. C. 4514	19 42 7	+ 1.62	+ 50 16.9	+ 8.6	»Planetary, bright, pretty large, round, star 11 m in the middle.» Closed nebula. Disc and border plainly shown.
G. C. 4565	20 12 22	+ 2.42	+ 30 15.5	+ 10.9	»Ring nebula, faint, small, very little extended.» Roberts II, plate 19 N:o 4. Faint, very perspicuous ring nebula, with nucleus. Small star on the northern part of the ring.
G. C. 4572	20 17 56	+ 2.68	+ 19 47.1	+ 11.3	»Planetary, bright, pretty small, round.» Ring nebula, pale, of great photographic intensity. A pretty bright star within the image of the nebula.

List of objects. Plate 6.

Object	Right Ascension 1900.0	Annual Precess.	Declination 1900.0	Annual Precess.	Description
G. C. 4827	$22^{h}\,36^{m}\,37^{s}$	+ 2.22	$+ 60^{\circ}\,45'.8$	$+ 18''.7$	»Planetary, bright, small, round, pretty gradually very little brighter in the middle.» Pretty distinct ring nebula, reminds of G. C. 2620. The reproduction fails to bring out the appearance of the original plate.
G. C. 4971	23 23 34	+ 2.99	+ 21 52.2	+ 19.8	»Very faint, pretty large, very little extended, little brighter in the middle.» Appears to be a spiral nebula. Reminds of G. C. 298.
G. C. 527	2 16 15	+ 3.74	+ 41 53.6	+ 16.7	»Brigth, very large, very much extended 22°.» This object proves to be a second species of planetary nebula, to which many of the very extended nebulæ may belong. The real shape of it is perhaps that of a hollow lens whose polar regions are very much denser than the equatorial ones.
G. C. 1267	5 41 37	+ 3.07	+ 0 0.8	+ 1.6	»Bright, large, wisp, gradually much brighter nucleus, 3 stars involved.» Second Orion Nebula.
G. C. 1267 & 5356	» 5 41 25	» »	» — 0 2.2	» »	Idem with attended nebula.
G. C. 1157	5 28 30	+ 3.60	+ 21 56.9	+ 2.9	»Very bright, very large, extended 135°.» Seems to be a spiral nebula of second species, helicoidally shifted in the direction of the original axis of the nebula. Two distorted branches are visible, one of which is pretty faint.
G. C. 1949	9 47 19	+ 5.07	+ 69 32.2	— 16.7	»Exceedingly bright, exceedingly large, extended 156°.» Spiral Nebula of the first species.
G. C. 4670	21 25 9	+ 2.90	+ 11 43.7	+ 15.6	Example of Globular Cluster.
G. C. 4447	18 49 52	+ 2.23	+ 32 54.3	+ 4.3	Ring nebula in *Lyra* enlarged.

Some of the very small and very bright planetary nebulæ, as for example G. C. 4373, G. C. 4390, N. G. C. 7027, G. C. 4964, are not reproduced here. The latter of these nebulæ is successfully photographed by Deslandres [Bulletin astronomique 1900, plates IX, X, XI.].

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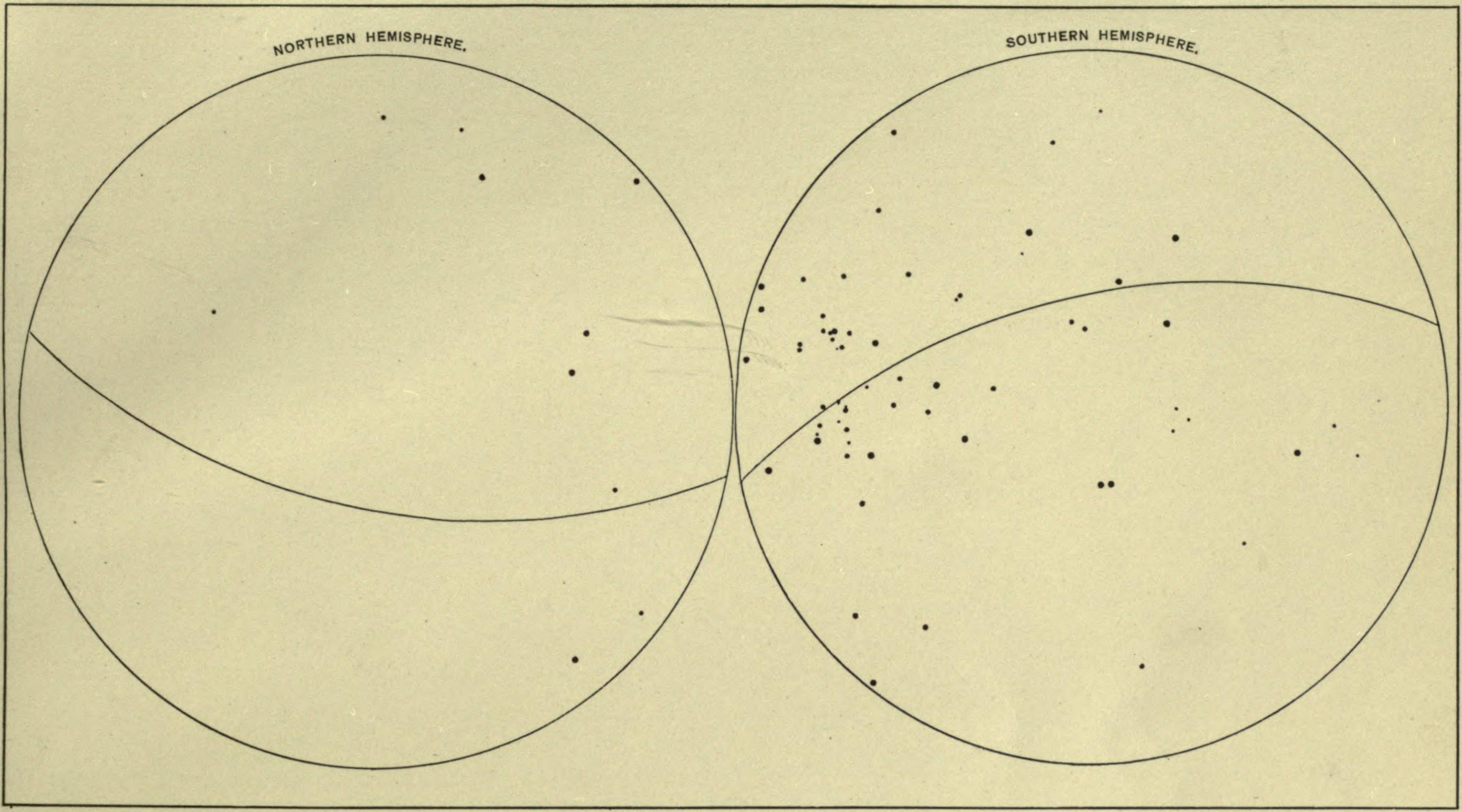
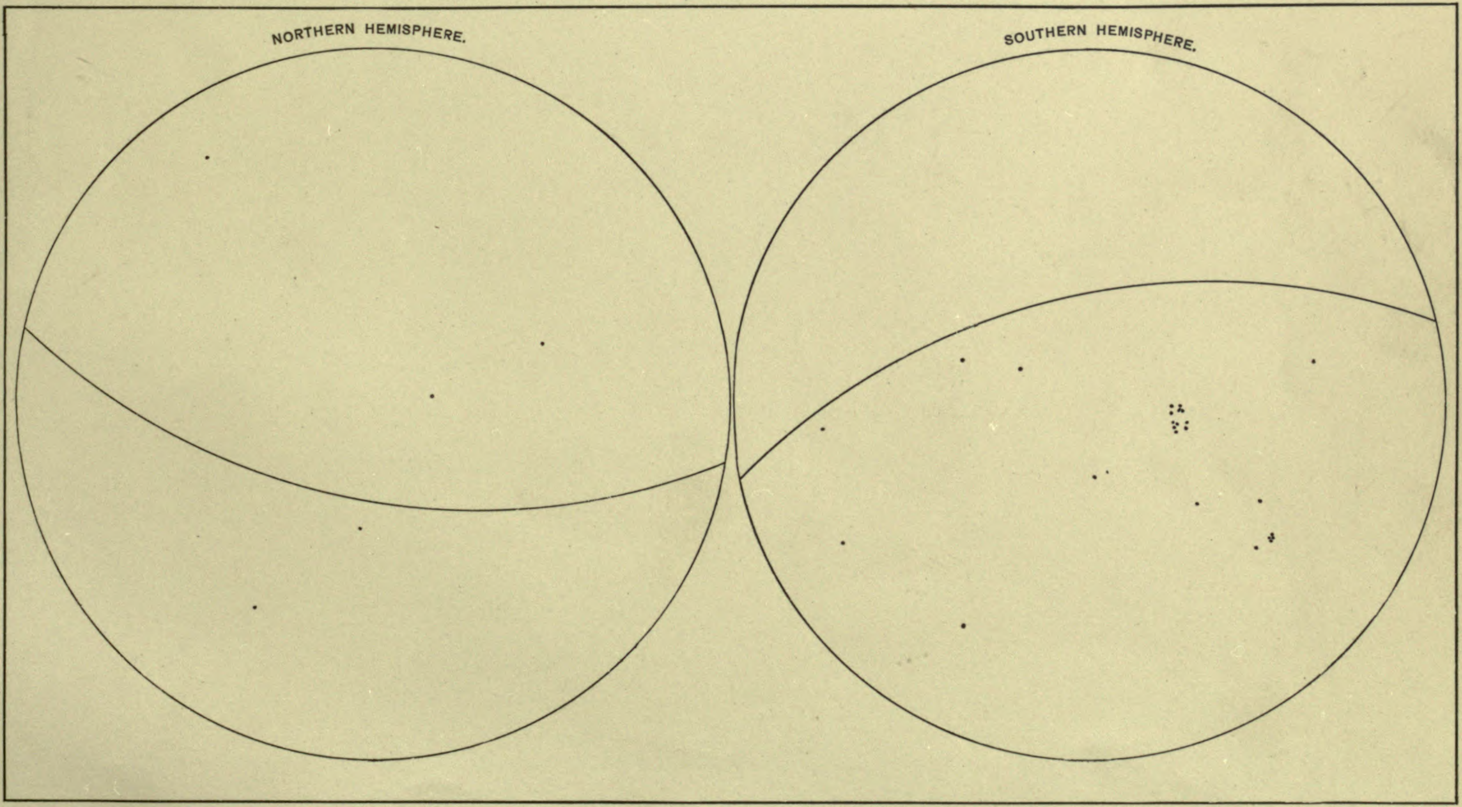


1. Distribution of Globular Clusters.



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2. Distribution of Globular Clusters.
Excluded Objects.

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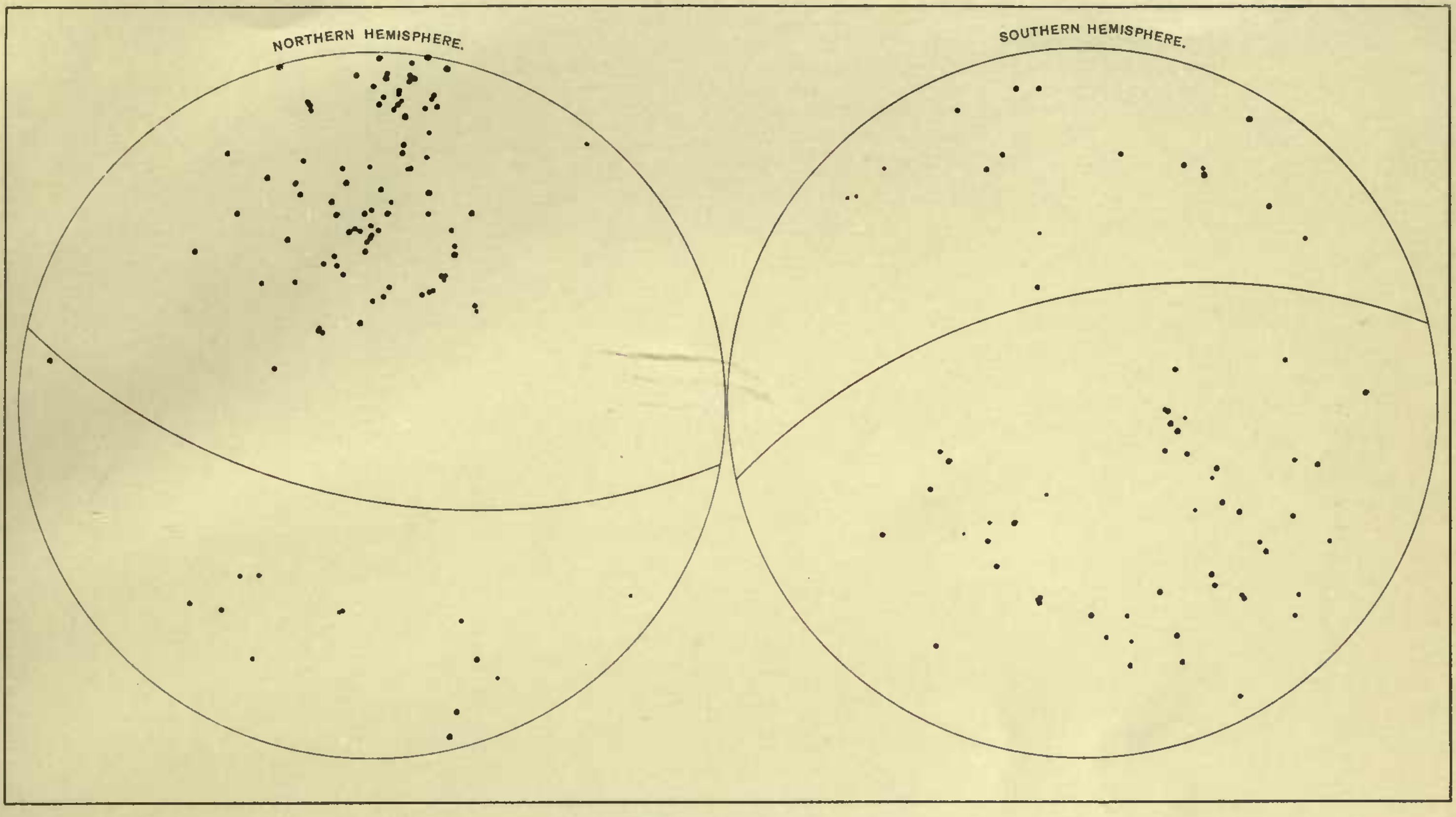
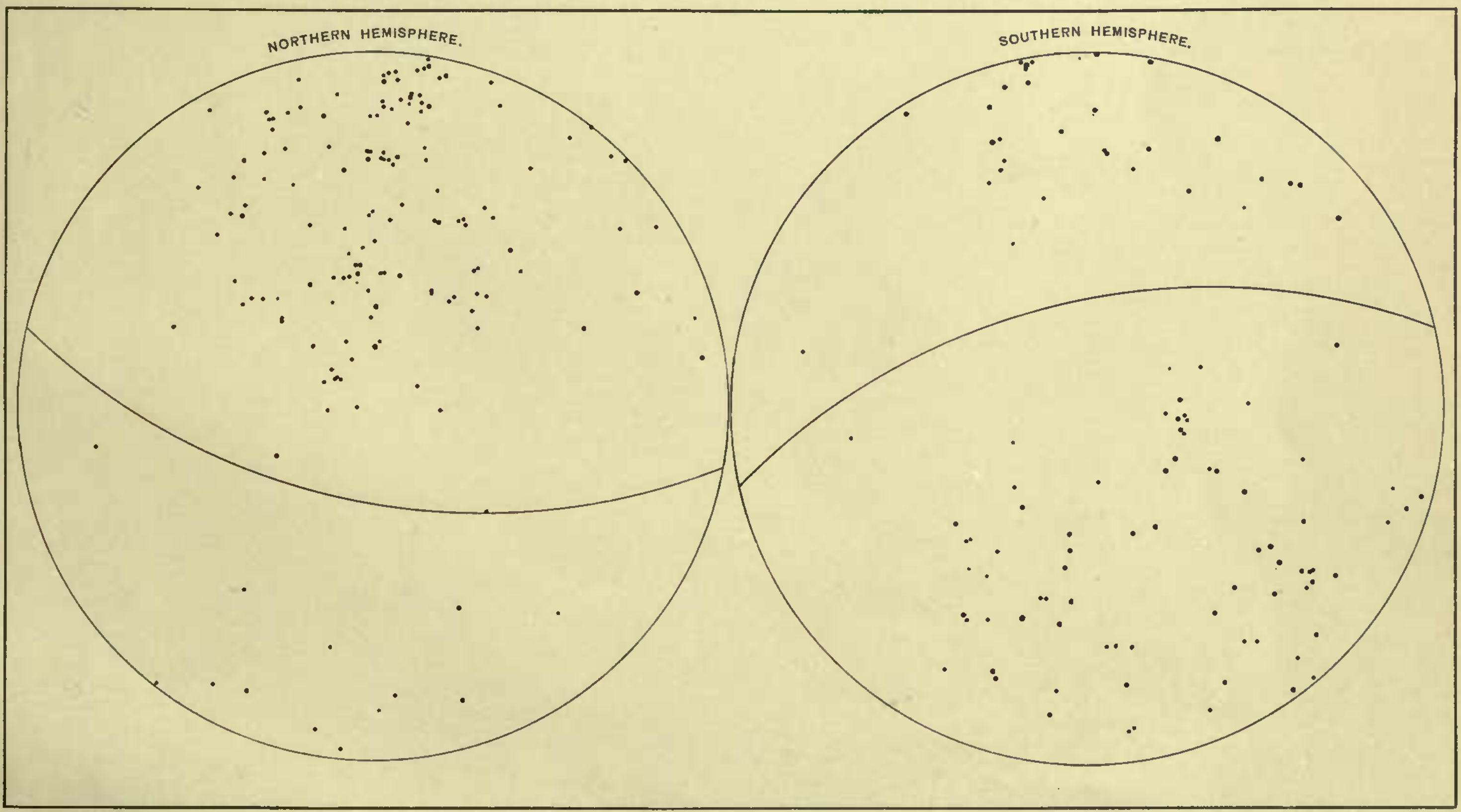


1. Distribution of Nebulæ, B, vE, eE.



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2. Distribution of Nebulæ, B, E, lE.

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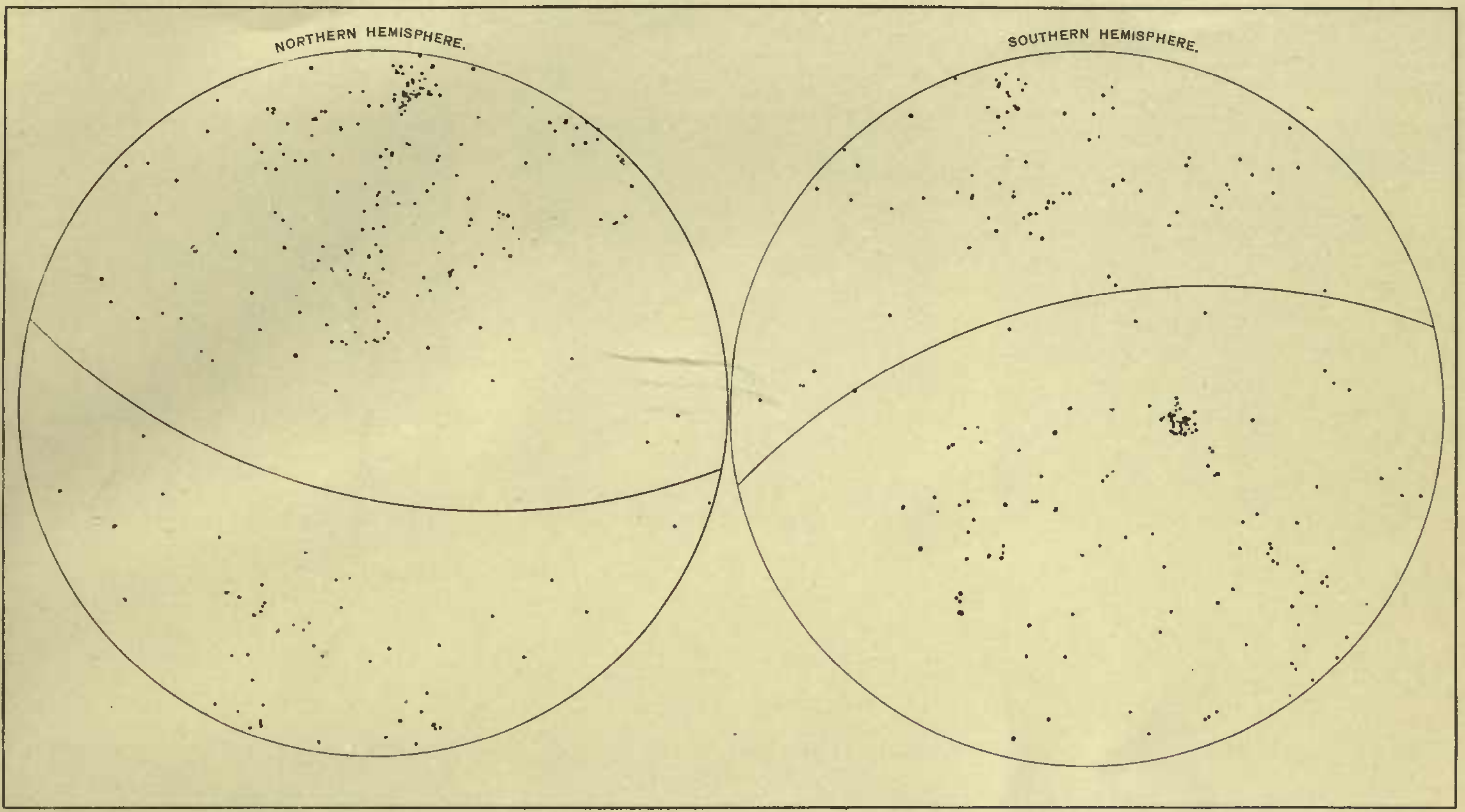
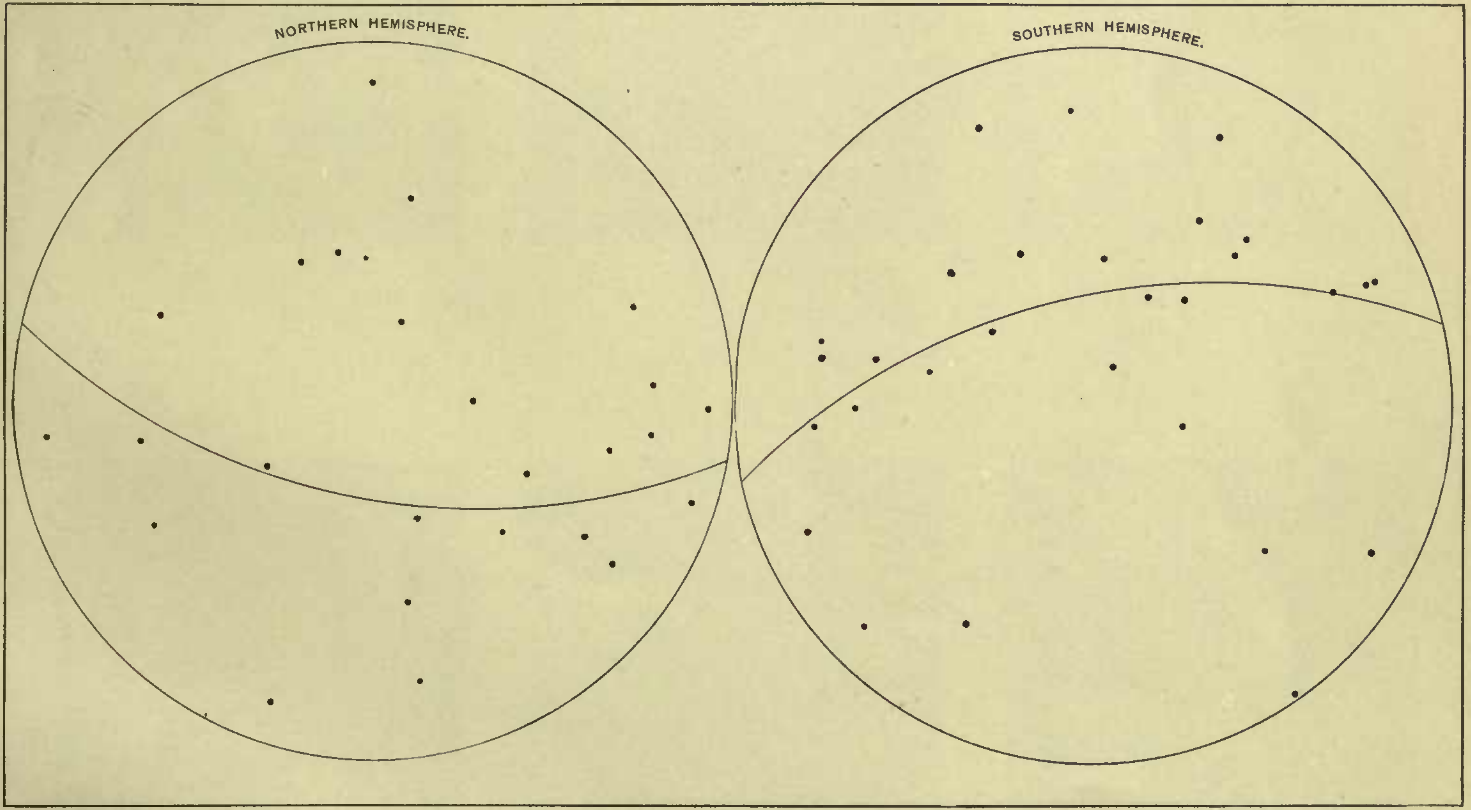


1. Distribution of Nebulæ, B, R.



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2. Distribution of Planetary Nebulæ.

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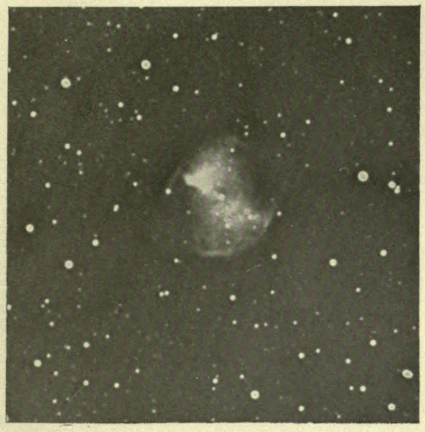
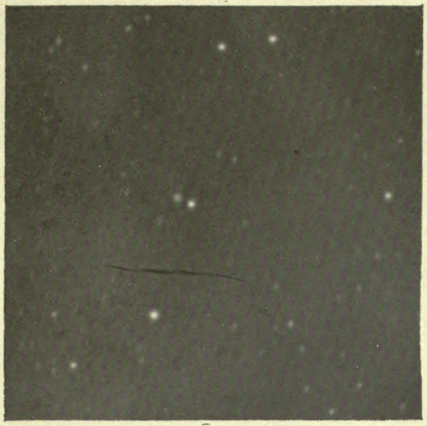
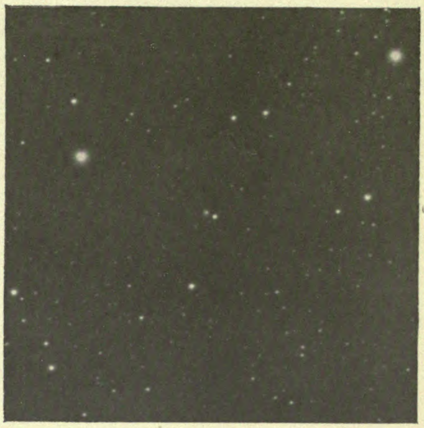


G. C. 4532



N. G. C. 7026



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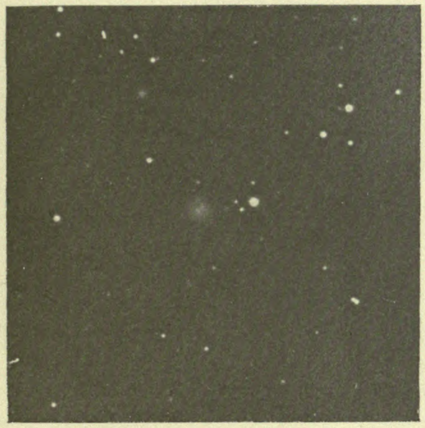

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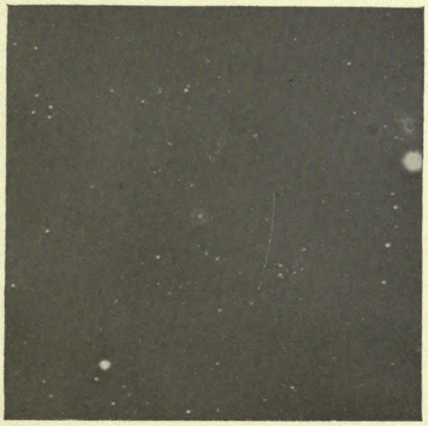

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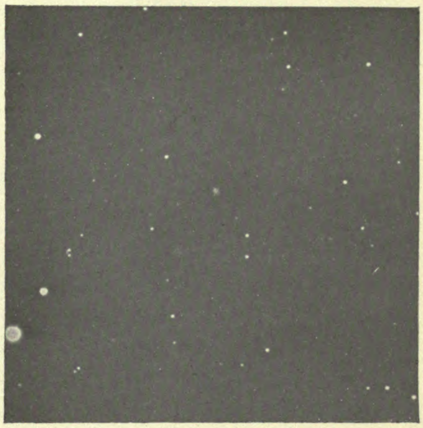
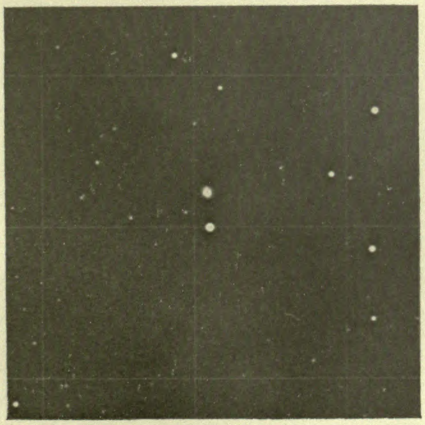
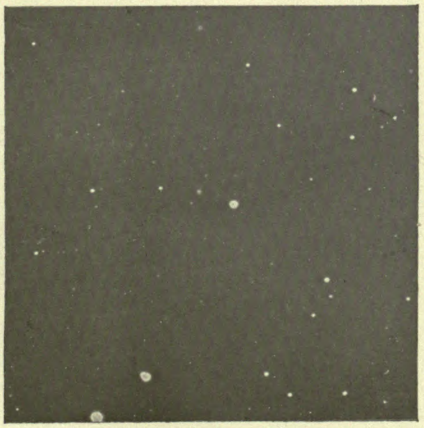


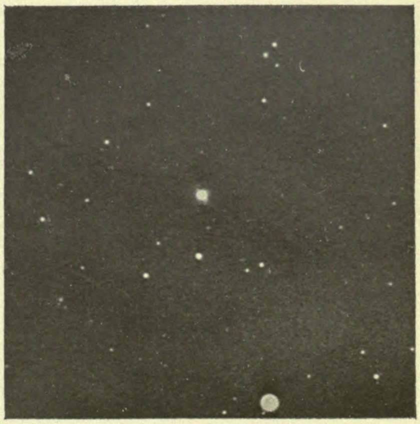
G. C. 1225



G. C. 1532



G. C. 1546



G. C. 2158

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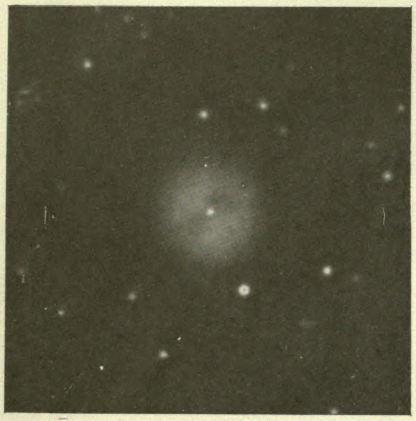
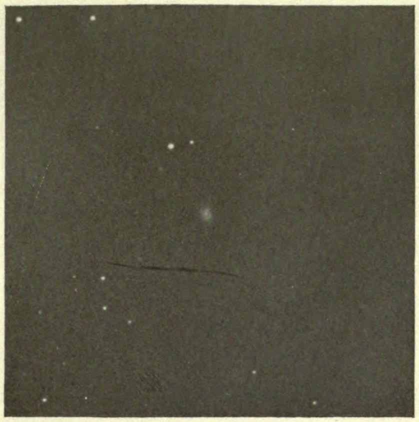
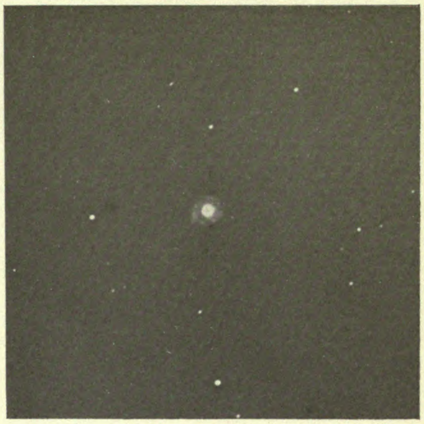


G. C. 2343



G. C. 2620



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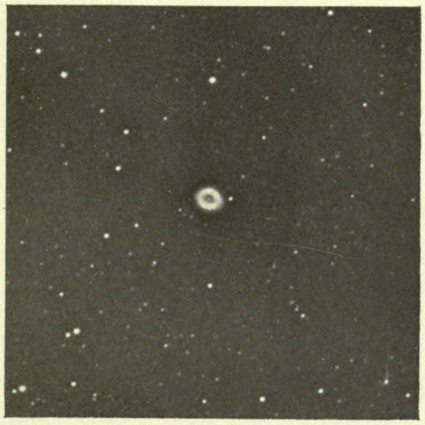

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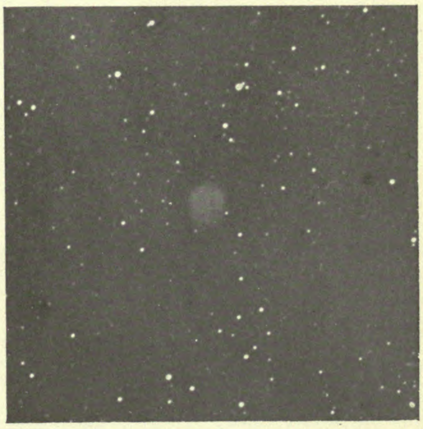

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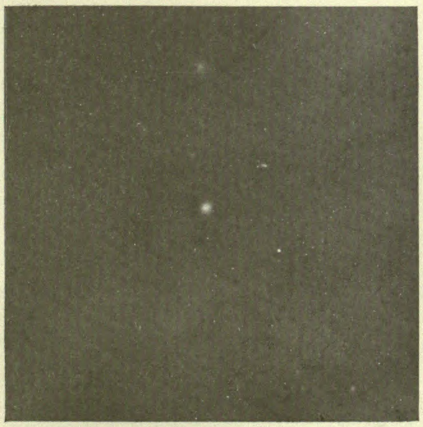

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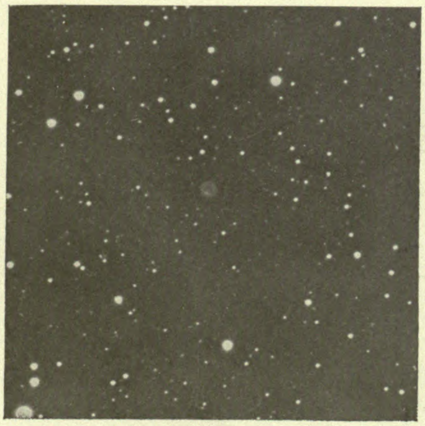

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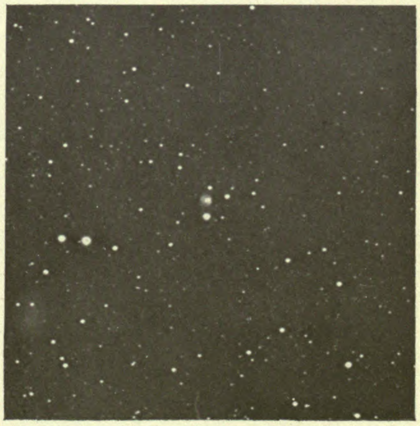

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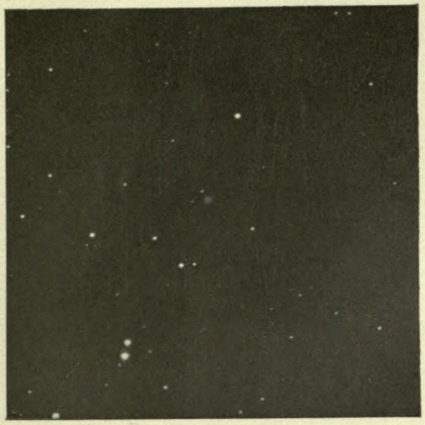
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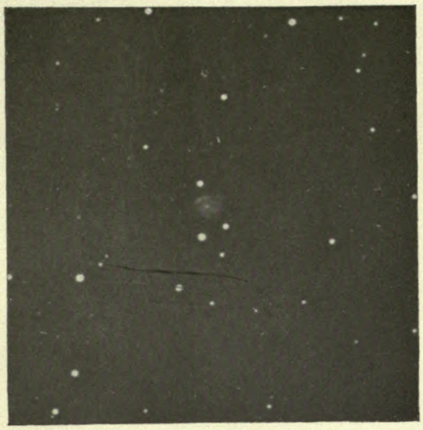
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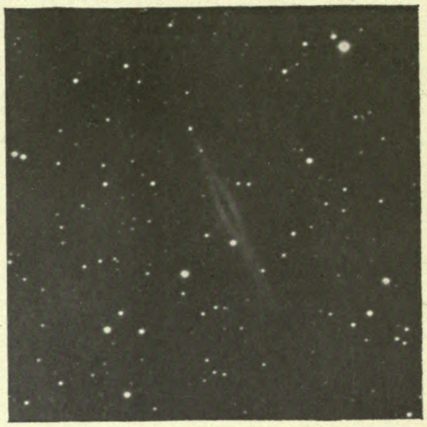
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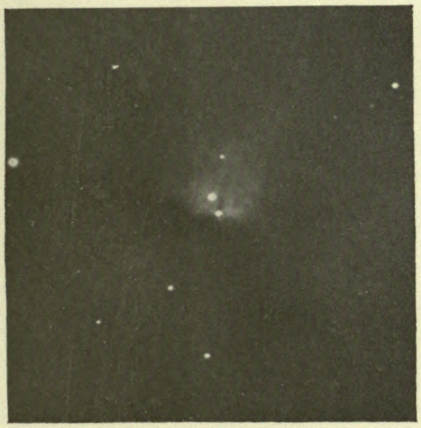
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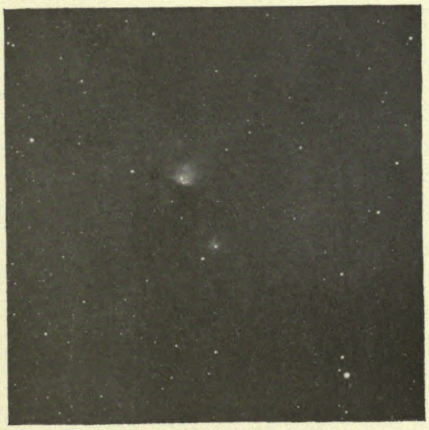
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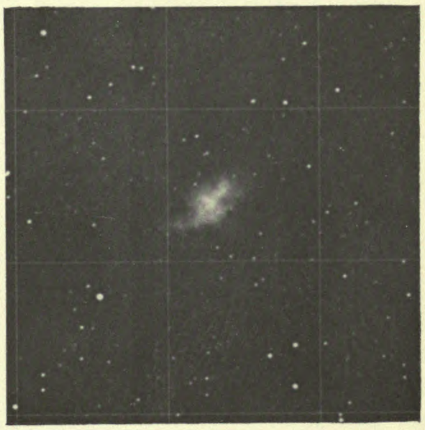
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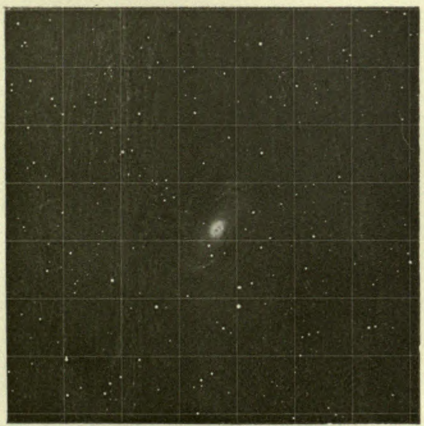
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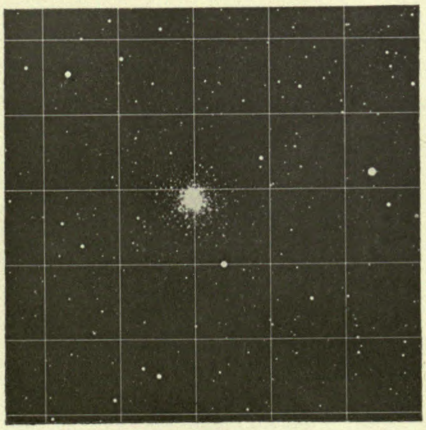
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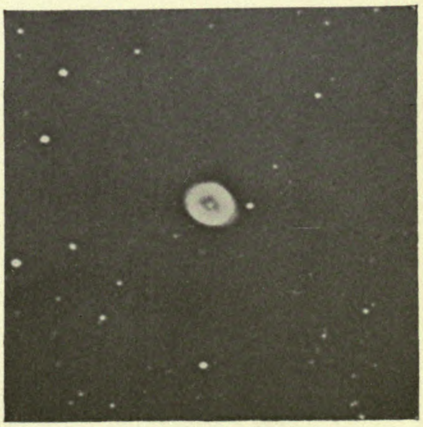
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